Demonstration of Catalytic NOx Reduction System Using Trace Hydrogen Injection

Grant ICAT 00-2

MEI-ARB01-FR

Final Report

Reporting Period:
February 20, 2001 – April 1 2004

Prepared By:

Makel Engineering, Inc.
1585 Marauder Street
Chico CA 95973

Prepared For:

Air Resources Board
Research Division
Sacramento, California 95812

1.0 Executive Summary

1.1 Project Summary

Makel Engineering Inc. (MEI) conducted pilot demonstration program under a grant from the California Air Resources Board (ARB) to develop a practical, low cost NOx emissions reduction system Suitable for lean burn natural gas fuel stationary power generators. This program directly supported the objectives of the ARB's Comprehensive Work Plan. In particular, this project supported the strategy in the 1994 State Implementation Plan (SIP) for achieving lower NOx emissions. The overall objectives of this project where:

- Build a prototype NOx emissions reduction system
- Perform design optimization tests
- Complete a field test demonstration

The resulting NOx emissions reduction system consists of a hydrogen production source, injection system, catalytic converter, sensors and control system. Laboratory tests were conducted at MEI and University of California at Berkeley (UCB). Once the design was completed optimization testing was conducted, and system refinements where made and the laboratory scale hardware was scaled up to be suitable for use on 100 to 250 kW class engines. Finally, a field test demonstration was commenced and performance data was gathered on a 100kw genset running in the field.

The resulting product addresses the need for effective NOx reduction systems for lean burn combustion devices. The initial target market for this technology is lean burn, natural gas powered reciprocating engines (stationary power generators). However, this technology may ultimately be adapted to diesel power generators and potentially to heavy-duty vehicles (CIDI engines) in conjunction with new particulate control systems and/or clean burning fuels currently under development.

In the presence of excess oxygen, conventional catalytic converters have very low NOx conversion rates. To address this limitation of existing technology, MEI's research represents an effective NOx reduction systems for lean burn combustion devices. The MicroNOx Trace Hydrogen Injection NOx reduction system is an exhaust after treatment system that is intended to be a system that can be used with existing natural gas or propane fueled lean burn engines without any modification to the engine control system. This system is applicable to both the retrofit and OEM engine/gen-set market. The system consists of a set of catalytic converters that are in parallel with each other and used in a cyclic fashion. The converters consist of NOx storage catalyst stages upstream of conventional 3-way catalytic converter. The converters are used to store NOx and are then regenerated with a hydrogen/carbon monoxide product stream from an external microchannel based reformer. System control is achieved using a NOx sensor downstream of the converters. With proper sizing of the NOx storage catalysts, the required fuel flow for regeneration of the catalyst is less than 0.5% of the total fuel flow to the engine.

This research culminated in a field-test of a 100 kW natural gas generator configured with a MicroNOx exhaust system. Figure 1 shows the genset and MicroNOx exhaust system. Specifications for the system is provided in Table 1

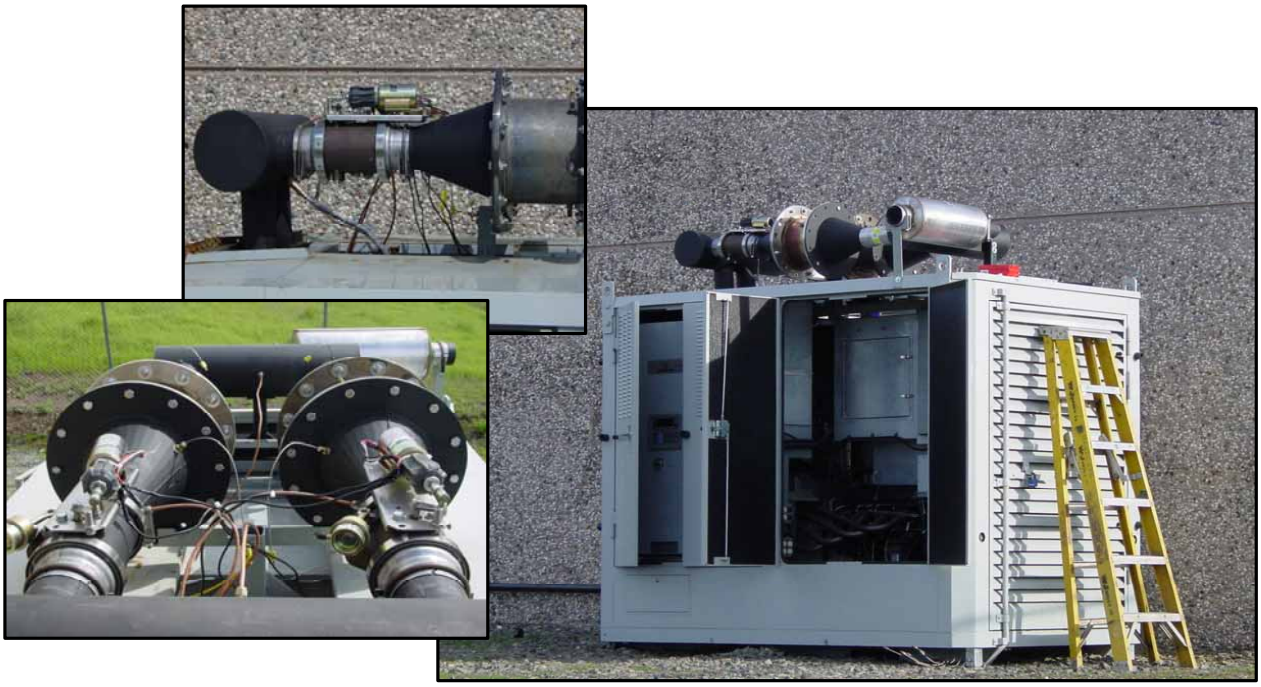

Figure 1. 100 kW Natural Gas Generator Set and MicroNOx Exhaust System For Field Testing

Table 1. MicroNOx System Operating Specifications

Fuel Type	Natural Gas or Propane (1)
Exhaust Inlet Temperature	350 C min
Maximum Inlet Temperature	TBD (estimated less than 550 C)
NOx Reduction	Greater than 80%
Fuel Consumption	Approximately 0.5%
Inlet Power	24 VDC
Power Consumption	12 W

The field test site was the Butte Community College water pumping system site demonstrates the technology's ability to utilize trace hydrogen to improve the NOx reduction efficiency of catalytic clean up of NOx emissions. The Butte College water pumping station relies on an aerobic digester system and a series of evaporation ponds. The field test generator replaces the 175kw diesel generator and operated offline through a switching system. The BCC waste treatment plant is based on a digester system. Raw sewage is pumped into a pumping well and run through two 5 hp sewage grinders. Two 7.5 hp lift pumps (Figure 2) feed the sewage into an aerobic digester (Figure 3). Two 25 hp blower (Figure 4) aerate the sewage in the digester system. These blowers and pumps run continuously alternating between electric motors. The processed sewage is released into a gravity flow system, pouring into a series of holding ponds where it evaporates.

Figure 2. Lifter Pumps.

Figure 3. Aerobic Digester.

Figure 4. 25 Hp blowers and existing diesel gen set

Testing with the final version of the system developed on this program demonstrated a NOx reduction of over 80% with up to 5% oxygen in the engine exhaust. The system was successfully operated over a nine-month field test with numerous starts as the system was typically used for sporadic short periods (typically a few hours).